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**ASSESSMENT OF IN-LINE FILTER TYPE AND CONDITION ON MEASUREMENT OF  
AMMONIA CONCENTRATION**

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**ABSTRACT.** *Gas analyzers are commonly protected from impurities in air sampling via use of in-line filters to ensure operational performance and longevity of the instruments. This is especially true for extended period of air monitoring under conditions where airborne dust exists. Prices for commercially available filters vary substantially. A question that has often come up but has not received much investigation is how the filter media type (e.g., paper vs. Teflon) and condition (clean vs. dirty) impact measurement of the gaseous concentration. The study reported here was conducted toward addressing this issue. Specifically, the study assesses the magnitude of ammonia (NH<sub>3</sub>) adsorption to different types of in-line filters and conditions often used or encountered in air sampling for animal feeding operation*

*air emission studies. The type of filters evaluated in this study included Teflon (most expensive), paper (less expensive), and stand-alone fuel filters, being either clean (new) or dust-laden. Three nominal NH<sub>3</sub> levels (20, 45, 90 ppm, generated with poultry manure) coupled with two nominal airflow rates (4 vs. 8 l/min or 8 vs. 16 l/min) through the filters were used in the evaluation. The type of dust used in this study included broiler house dust and starch. Simultaneous measurements of NH<sub>3</sub> concentrations before and after the tested filter were made with two photoacoustic gas spectrometers. The results revealed that initial NH<sub>3</sub> adsorption was highest for the fuel filter but negligible for the Teflon filters. However, after 30-min exposure the relative NH<sub>3</sub> adsorption by the filters were mostly below 1%. During fresh-air purging of the fuel filters laden with broiler house dust, ammonia was initially released but quickly diminished after 15 minutes. Flow rate was inversely related to NH<sub>3</sub> adsorption by the filter, particularly dust-laden filters. The result suggest that when used properly, the in-line filters tested in this study (fuel, paper and Teflon) all offer viable options for air emission measurement applications.*

**Keywords.** *Ammonia adsorption, Dust filter, Air sampling integrity, Air quality, Air emissions*

## INTRODUCTION

Ammonia ( $\text{NH}_3$ ) generation and emission are associated with animal feeding operations due to biological decomposition of the manure. Because of its environmental impact, quantification and mitigation of  $\text{NH}_3$  emissions for animal production systems continue to receive increasing attention from the animal industry, regulatory agencies and scientific communities (Li et al., 2006; Liang, et al., 2006; Wheeler et al., 2006; Xin, 2006). Reasonably accurate measurements of  $\text{NH}_3$  emissions from animal feeding operations are critical for evaluating the effectiveness of potential mitigation techniques and for establishing fair and equitable regulations (Wathes et al., 1998). The two key elements in determining the magnitude of aerial emissions from animal facilities are concentration of the aerial pollutant and ventilation rate through the facilities. Although not the focus of this paper, considerable research has been conducted concerning quantification of animal building ventilation rate (Demmers et al., 2000, 2001; Gates et al., 2004; Li et al., 2005; Muhlbauer et al., 2006; Xin et al., 2006).

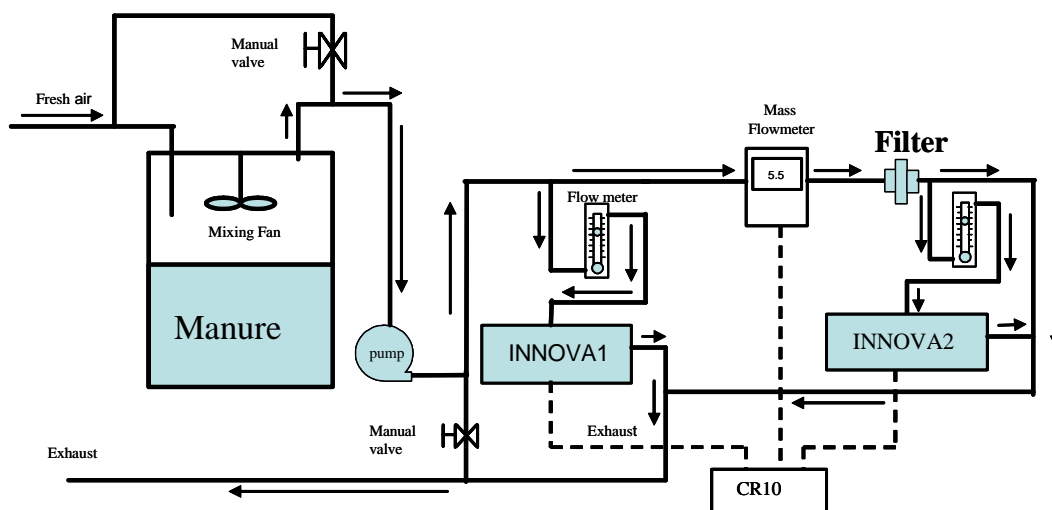
Previous studies have used different methods and instruments to measure gaseous, particularly  $\text{NH}_3$  concentrations in animal facilities, including electrochemical sensors (Xin et al., 2002, 2003; Liang, et al., 2004, Gates, et al., 2005), chemiluminescence detector (Phillips, et al., 1998, Heber et al., 2001; Liang et al., 2004), and photoacoustic spectrometer (Zhang et al., 2005; Burns et al., 2006; Li et al., 2006). Regardless of the working principles of the gas analyzers, their operation must be protected from the dust-laden environment when sampling air streams in animal production facilities to ensure measurement performance and longevity of the instruments. Mukhtar et al. (2003) reported that  $\text{NH}_3$  adsorption onto LDPE tubing was significantly higher than that of Teflon; and that tubing length was not significant in  $\text{NH}_3$  adsorption onto Teflon. Capareda et al. (2004) reported the same result. It has also been reported that gaseous  $\text{NH}_3$  will adsorb to dust particles (Takai et al., 2002; Lee and Zhang, 2006). However, research is meager that quantifies the impacts of media type and conditions of in-line dust filters on  $\text{NH}_3$  adsorption.

The objective of this study was to evaluate the magnitude of  $\text{NH}_3$  adsorption onto Teflon, fuel or paper type of filters under clean or dust-laden conditions over a range of  $\text{NH}_3$  concentrations and in-line air flow rates.

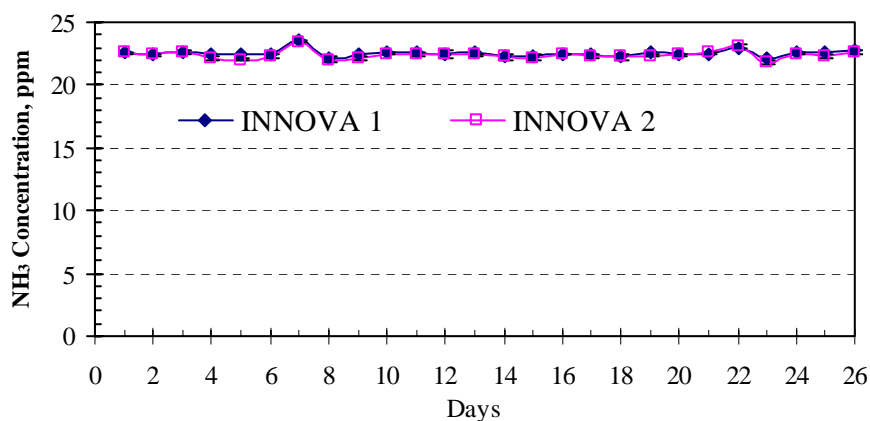
## MATERIALS AND METHODS

### MEASUREMENT SYSTEM SETUP

Ammonia concentrations before and after the dust filter under evaluation was measured simultaneously using two photoacoustic multi-gas spectrometers (model 1412, Innova AirTech Instrument, Denmark). The evaluation system (fig.1) was located inside an environmentally controlled room where the air temperature was maintained at  $21.1^\circ\text{C}$  throughout the experiment. Prior to each evaluation trial, zero ( $\text{N}_2$ ) and span (22.6 ppm  $\text{NH}_3$  +  $\text{N}_2$  balance,  $\pm 2\%$  accuracy) calibration gases (Matheson Tri-Gas, Inc. , La Porte, Texas, USA) were used to calibrate and check both gas analyzers to ensure their integrity and exchangeability. Performance of the two gas analyzers throughout the testing period (fig. 2) revealed that the differences between the two units were within their measurement sensitivity (1% or 0.2 ppm).



**Figure 1. Schematic of the experimental apparatus for evaluating impact of in-line filters on ammonia adsorption.**



**Figure 2. Responses of the two Innova 1412 gas analyzers to daily ammonia span (22.6 ppm) check.**

For the filter evaluation trials, poultry manure held in a sealed 19-liter container with a top-mounted mixing fan was used to generate ammonia (fig.1). Different NH<sub>3</sub> concentrations from the source were achieved by controlling the amount of fresh air into the manure container. Teflon tubing (0.64 mm OD, 0.32 mm ID) was used throughout the system. Airflow rate through the filter was measured using a mass flow meter (0-10 l/min, McMillan Company, Georgetown, Texas). A programmable data acquisition system (model CR10X, Campbell Scientific, Inc, Logan, Utah, USA) was used to log the analog output from both gas analyzers, the mass flow meter and an ambient temperature and relative humidity probe. The output readings were sampled at 20-s intervals and stored as one-minute averages.

The testing conditions for the study are listed in Table 1, and are described below. Selection of the flow rate for each filter was based on their likely placement in the sample lines.

#### DUST FILTERS

Four types of in-line dust filters that may be used in air sampling were tested in this study, including two varieties of Teflon filter, a fuel filter and a paper filter. The two varieties of Teflon membrane filters were a) model 1141 featuring 47 mm O.D., 5-6 µm pore size, and 0.10 mm thick

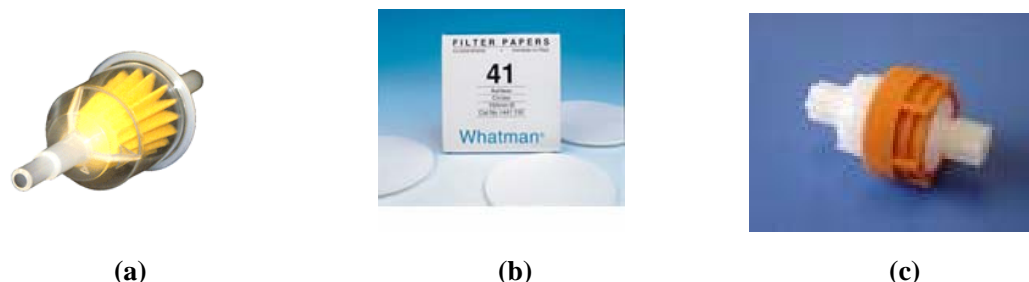
membrane; and b) model 1151 featuring 47 mm O.D., 20-30  $\mu\text{m}$  pore size, and 0.14 mm thick membrane (Saville. Minnetonka, MN, USA). The fuel filter was a NAPA fuel filter (model 3011, made in Israel), and the paper filter had a 47 mm O.D. and a 20-25  $\mu\text{m}$  pore size (model 41, Whatman International Ltd., England). The filter membrane was held in a Teflon filter holder. A photographical view of the filters is shown in Figure 3.

**Table 1. Filter type, flow rate and ammonia concentrations used in the ammonia adsorption tests**

Filter type	Nominal Flow Rate, l/min <sup>*</sup>	Nominal NH <sub>3</sub> Concentration, ppm <sup>**</sup>	Dust Type/Source
New fuel filter	4, 8	20, 45, 90	None or Starch
Dust-laden fuel filter	4, 8	20, 45, 90, fresh air	Broiler house dust
New Teflon filter	8, 16	20, 45, 90	None or Starch
Dust-laden Teflon filter	8, 16	20, 45, 90, fresh air	Broiler house dust
New Paper filter	8, 16	20, 45, 90	None or Starch

\* The actual range of flow rate corresponding to the nominal values of 4, 8 and 16 l/min were 4.0–4.2, 7.9–8.3, and 14.0–15.7 l/min, respectively.

\*\* The actual range of NH<sub>3</sub> concentration the nominal values of 20, 45, and 90 ppm were 18.5–26.7, 36.8–59.0, and 62.0–97.0 ppm, respectively. Fresh air had nearly zero NH<sub>3</sub>.



**Figure 3. A photographical view of the fuel filter (a), membrane filters (b) and filter holder (c) used in this study.**

## DUST GENERATION AND MEASUREMENT

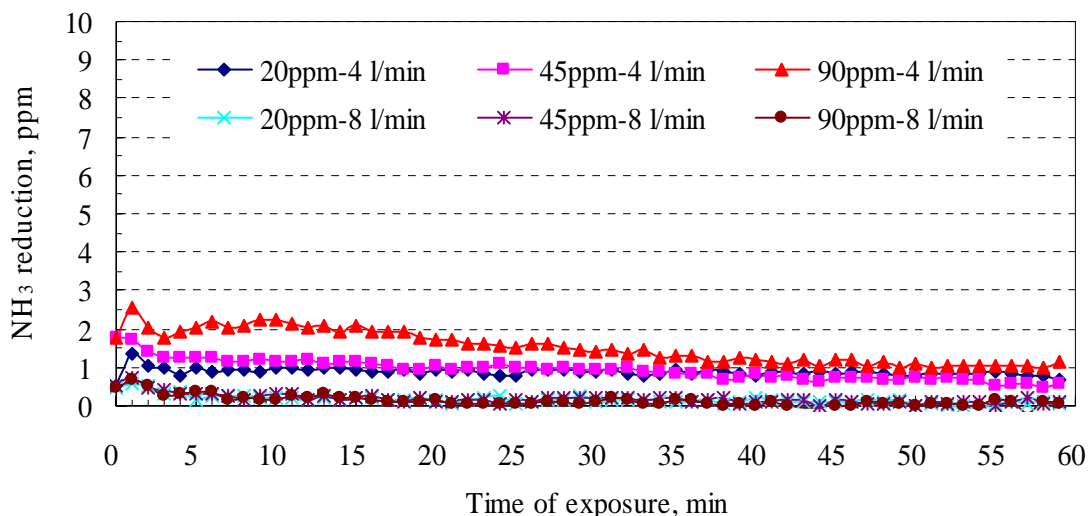
To determine the NH<sub>3</sub> adsorption effect of dust on filter, two types of dust were examined: a) used filters laden with some amount of broiler housing dust; and b) new filters laden with NH<sub>3</sub>-free starch. To load the new filters with the NH<sub>3</sub>-free starch dust, starch was put in a sealed (19-liter) bucket and a mixing fan was used to generate dust. A new fuel filter or filter assembly was connected via Teflon tubing between the dust source and a vacuum pump that drew air from the dust-generation bucket. For the used dust-laden filters, they were from an ongoing project that monitored air emissions from broiler houses (Burns et al., 2006), and had been in operation (as the first-stage filtration) in the air sample lines for one week. For the new filters, they were oven-dried (model 650G, Fisher Scientific International Inc., USA) at 105°C for 24 hours before and after dust loading, and weighed using an electronic balance (accuSeries II, model accu-224,

Single Range, Weighing Range: 0 to 220 g, Fisher Scientific International Inc.) to determine the amount of dust on the filter. For the used filters, they were weighed before the test and weighed again following knock-out of the dust as much as possible to estimate the amount of dust carried on the filters. The absolute and relative reductions in  $\text{NH}_3$  concentration before and after the tested filter were used to express the  $\text{NH}_3$  adsorption onto the filter.

## RESULTS AND DISCUSSION

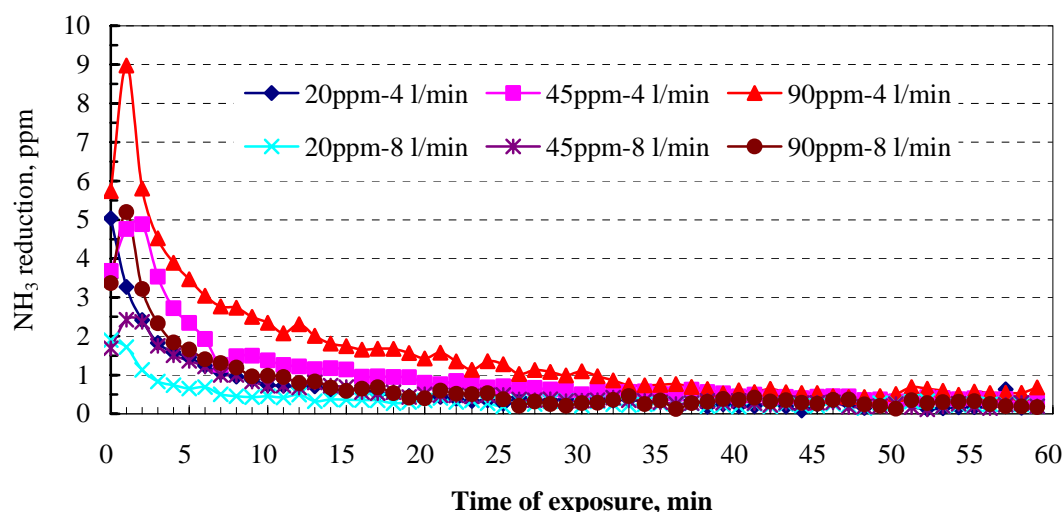
### AMMONIA ADSORPTION BY DIFFERENT FILTERS

**Fuel Filter.** The  $\text{NH}_3$  adsorption profiles for the new, dust-free fuel filter over a 60-min exposure to the combinations of different  $\text{NH}_3$  concentrations and flow rates are shown in Figure 4. It can be noted that for a given  $\text{NH}_3$  concentration, higher flow rate through the filter generally led to less  $\text{NH}_3$  adsorption, presumably a result of shorter contacting time. For a given flow rate, higher concentration led to greater  $\text{NH}_3$  adsorption. The data also showed that  $\text{NH}_3$  adsorption by the fuel filter was 1 ppm or less after 10 minutes of exposure for all the concentration-flow rate combinations except for the 90 ppm-4 l/min regimen which approached 1 ppm or lower after 50-min exposure.



**Figure 4. Ammonia absorption by dust-free new fuel filter at different combinations of  $\text{NH}_3$  concentrations and flow rates (mean of 4 replicates per regimen).**

The  $\text{NH}_3$  adsorption profiles for the fuel filter laden with starch dust over a 60-minute exposure to various  $\text{NH}_3$  concentrations and flow rates are shown in Figure 5 and are further summarized in Table 2.



**Figure 5. Ammonia absorption by (starch) dust-laden new fuel filters at different combinations of ammonia concentration and flow rates (mean of 4 replicates per regimen).**

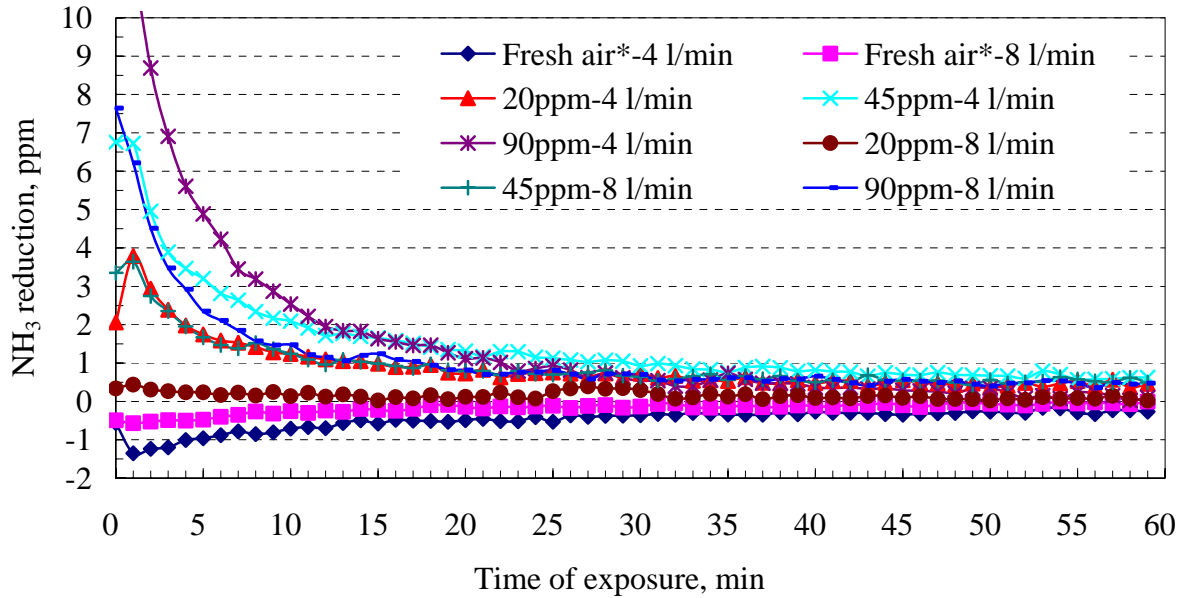
**Table 2. Ammonia adsorption by new fuel filter laden with starch dust (n =4, mean  $\pm$  SD)**

Flow Rate (l/min)	Nominal inlet NH <sub>3</sub> (ppm)	NH <sub>3</sub> adsorption (mg over 1 hr)	Dust laden on filter (g)	Specific NH <sub>3</sub> adsorption by dust (mg·g dust <sup>-1</sup> over 1 hr)
4	20	0.12( $\pm$ 0.02)	0.19( $\pm$ 0.03)	0.61( $\pm$ 0.10)
	45	0.18( $\pm$ 0.03)	0.34( $\pm$ 0.14)	0.60( $\pm$ 0.22)
	90	0.29( $\pm$ 0.07)	0.24( $\pm$ 0.04)	1.20( $\pm$ 0.24)
8	20	0.14( $\pm$ 0.02)	0.23( $\pm$ 0.06)	0.62( $\pm$ 0.08)
	45	0.21( $\pm$ 0.10)	0.35( $\pm$ 0.23)	0.69( $\pm$ 0.05)
	90	0.26( $\pm$ 0.12)	0.27( $\pm$ 0.13)	1.01( $\pm$ 0.32)

Adsorption of ammonia generally decreased as flow rate increased or under lower NH<sub>3</sub> concentrations for a given flow rate. Initially, NH<sub>3</sub> adsorption by the (starch) dust-laden filter was high, up to 9.0 ppm for the 90 ppm-4 l/min regimen; but the difference decreased rapidly with time. After 30-min exposure, the difference was reduced to 1 ppm or less for all the testing regimens. The total amount of NH<sub>3</sub> adsorption by the (starch) dust-laden filter tended to increase with inlet NH<sub>3</sub> concentration.

Similar results for the used fuel filter laden with broiler house dust were observed (fig. 6 and Table 3) when NH<sub>3</sub>-laden air passed through the filters. However, when fresh air passed through the used filters, there was an initial NH<sub>3</sub> release, with the magnitude of NH<sub>3</sub> difference somewhat depending on the flow rate. The 8 l/min flow rate led to smaller difference presumably due to more dilution (nearly zero after 20 min) than the 4 l/min flow rate (<0.5 ppm after 20 min).





**Figure 6. Ammonia (NH<sub>3</sub>) absorption by used fuel filter laden with broiler house dust for different combinations of NH<sub>3</sub> concentration and flow rate (mean of 4 replicates per regimen)**

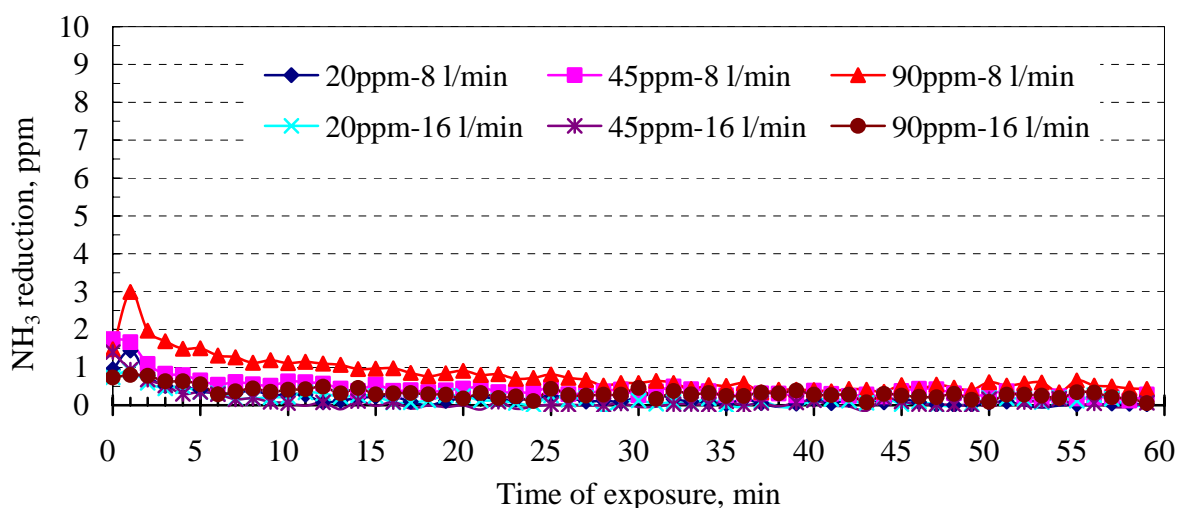
**Table 3. Ammonia adsorption by used fuel filters laden with broiler house dust (n =4, mean  $\pm$  SD)**

Flow Rate (l/min)	Nominal inlet NH <sub>3</sub> (ppm)	NH <sub>3</sub> adsorption (mg over 1 hr)	Dust laden on filter (g)	Specific NH <sub>3</sub> adsorption by dust (mg·g dust <sup>-1</sup> over 1 hr)
4	20	0.16( $\pm$ 0.05)	0.11( $\pm$ 0.06)	2.32( $\pm$ 1.99)
	45	0.27( $\pm$ 0.03)	0.11( $\pm$ 0.04)	2.72( $\pm$ 1.05)
	90	0.31( $\pm$ 0.01)	0.20( $\pm$ 0.03)	1.60( $\pm$ 0.20)
8	20	0.06( $\pm$ 0.04)	0.15( $\pm$ 0.06)	0.15( $\pm$ 0.07)
	45	0.21( $\pm$ 0.10)	0.14( $\pm$ 0.03)	2.48( $\pm$ 0.28)
	90	0.41( $\pm$ 0.02)	0.24( $\pm$ 0.30)	1.75( $\pm$ 0.29)

**Paper Filter.** The NH<sub>3</sub> adsorption profiles for the new, dust-free paper filter over a 60-min exposure to the combinations of different NH<sub>3</sub> concentrations and flow rates are shown in Figure 7. The adsorption profiles for the new paper filter resembled those of the new fuel filter. However, comparing the fuel filter and the paper filter at the same flow rate of 8 l/min, the paper filter showed somewhat higher NH<sub>3</sub> adsorption. Nonetheless, the reduction mostly (except for 90 ppm-8 l/min) decreased to < 0.5 ppm after 30-min exposure for all the regimens.

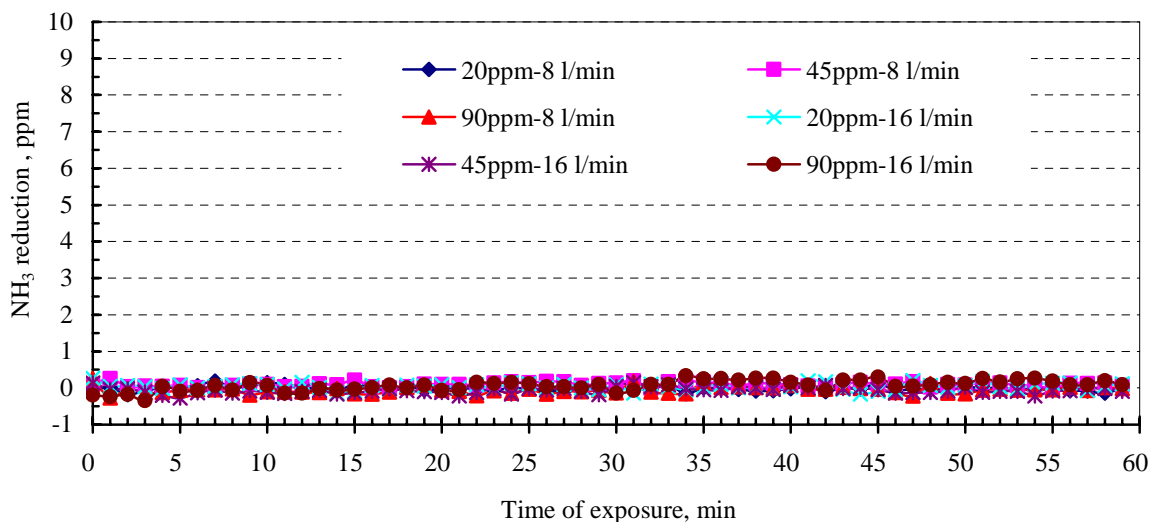
**Teflon Filters.** Figures 8 and 9 show the NH<sub>3</sub> adsorption profiles for the new, dust-free Teflon filters with a pore size of 20 $\mu$ m or 5 $\mu$ m. The differences in NH<sub>3</sub> concentration between the inlet and the outlet air in all cases were well within the measurement sensitivity (0.2 ppm) of the gas analyzer. Similar results were observed for the used Teflon filters laden with broiler house dust (fig. 10). Since the pore size of 20 $\mu$ m or 5 $\mu$ m did not seem to impact the NH<sub>3</sub> adsorption characteristics of the Teflon filters, they were not differentiated. The filters had been in operation in our broiler air emission sampling lines for 14 days;

however no attempt was made to determine the amount of dust collected on the filters.

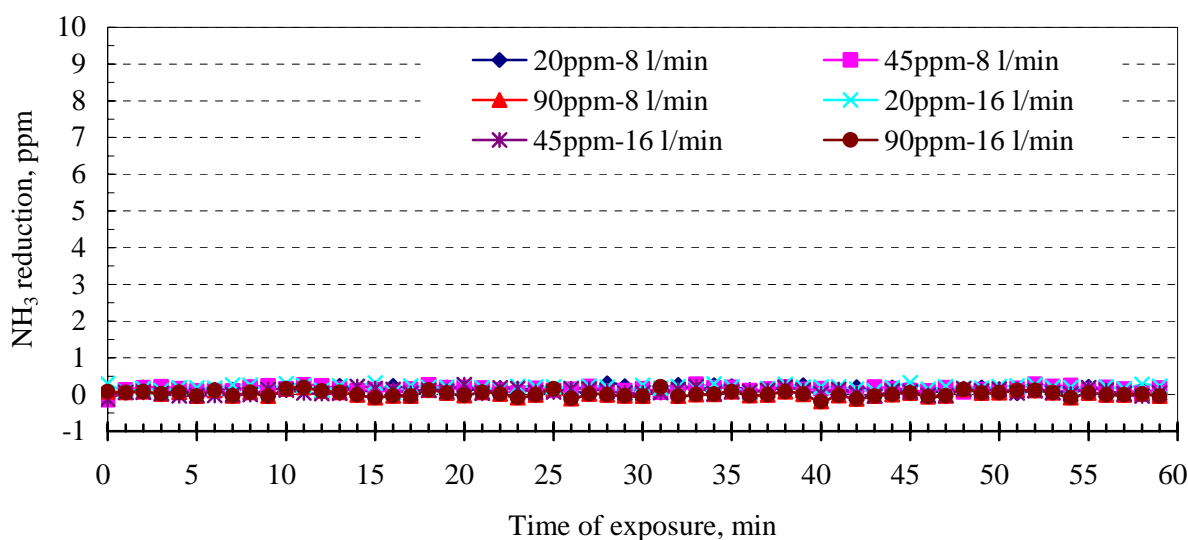


**Figure 7. Ammonia ( $\text{NH}_3$ ) absorption by new paper disk filter for different combinations of  $\text{NH}_3$  concentration and flow rate (mean of 3 replicates per regimen)**

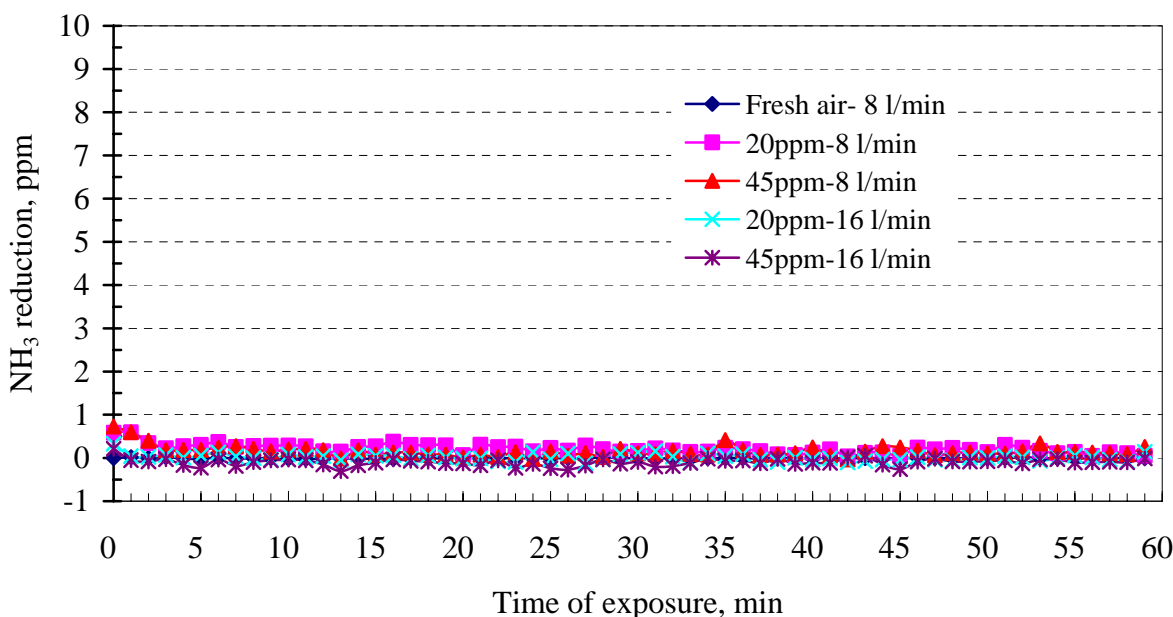
The  $\text{NH}_3$  adsorption or release characteristics of the tested filters are further summarized in Table 4. In addition to the absolute values in  $\text{NH}_3$  concentration change between the inlet and outlet of the filter, the change was expressed as percentages of the inlet value. As it can be noted from the data in Table 4, the relative deviation caused by the filter media and operating condition was mostly less than 1% and occasionally as high as 3% after 60-min sample exposure. Hence, for practical purposes of monitoring air emissions in animal feeding operations, all the in-line filters tested in this study and their typical operating conditions are expected to function well.



**Figure 8. Ammonia absorption by dust-free Teflon filter with pore size of  $20\mu\text{m}$  at different combinations of  $\text{NH}_3$  concentrations and flow rates (mean of 3 replicates per regimen).**



**Figure 9 . Ammonia absorption by dust-free Teflon filter with pore size of  $5\mu\text{m}$  at different combinations of  $\text{NH}_3$  concentrations and flow rates (mean of 3 replicates per regimen)**



**Figure 10. Ammonia absorption by used Teflon filter laden with broiler house dust for different combinations of  $\text{NH}_3$  concentration and flow rate (mean of 3 replicates per regimen)**

#### ASSESSMENT OF MAIN INFLUENCING FACTORS ON $\text{NH}_3$ ADSORPTION ONTO FILTERS

In an attempt to assess the impact of exposure time, inlet concentration and flow rate on  $\text{NH}_3$  adsorption onto the filters, regression analysis was performed for the fuel and paper filters. Because  $\text{NH}_3$  adsorption for the clean or dust-laden Teflon filters (both pore sizes) was lower than the sensitivity of the gas analyzer ( $<0.2$  ppm), its regression analysis was omitted. Moreover, since differences in  $\text{NH}_3$

concentration approached stabilization and mostly less than 1% of the inlet value after 30 min of exposure for the tested filters and condition, regression was performed for the first 30-min exposure. The regression results for the fuel and paper filters are shown below. All the constant and coefficients in the equations are significant at the 0.15 level.

*For new, dust-free fuel filter:*

$$\text{NH}_3 \text{ diff} = 2.30473 - 0.01426 \cdot t + 0.00671 \cdot C_{\text{inlet}} - 0.27534 \cdot F \quad (R^2=0.85) \quad [1]$$

*For new fuel filter with NH<sub>3</sub>-free (starch) dust:*

$$\text{NH}_3 \text{ diff} = 2.92627 - 0.09042 \cdot t + 0.01491 \cdot C_{\text{inlet}} - 0.19412 \cdot F \quad (R^2=0.62) \quad [2]$$

*For used fuel filter with broiler house dust:*

$$\text{NH}_3 \text{ diff} = 3.65595 - 0.12391 \cdot t + 0.02420 \cdot C_{\text{inlet}} - 0.25277 \cdot F \quad (R^2=0.51) \quad [3]$$

*For new, dust-free paper filter:*

$$\text{NH}_3 \text{ diff} = 1.16256 - 0.02642 \cdot t + 0.00696 \cdot C_{\text{inlet}} - 0.06027 \cdot F \quad (R^2=0.67) \quad [4]$$

Where  $\text{NH}_3 \text{ diff}$  = difference in  $\text{NH}_3$  concentration between inlet and outlet, ppm

$t$  = exposure or run time, min ( $t=0-30$  min)

$C_{\text{inlet}}$  = actual ammonia concentration at the inlet of filter, ppm

$F$  = actual air flow rate through the filter, l/min

Equations 1 to 4 depict that  $\text{NH}_3$  adsorption was positively related to inlet concentration but negatively related to exposure time and flow rate. It should be noted that the above empirical equations are only valid for the range of exposure time (0-30 min),  $\text{NH}_3$  concentration range (20-94 ppm), and flow rate (4-8 or 8-16 l/min) used in the experiment.

**Table 4. Ammonia adsorption by in-line filters of different types and operating conditions (new vs. dust-laden), expressed in concentration change before and after the filter and percentage of the inlet value. Negative values represent release of ammonia by the filter laden with broiler house dust.**

Filter Type & Status	Flow Rate (l/min)	Nominal NH <sub>3</sub> Level (ppm)	NH <sub>3</sub> Concentration Change after Various Exposure Time, mean (SD)					
			1 min	5 min	10 min	20 min	40 min	60 min
FF – new, dust free (n=4)	4	20	0.50(2.6%)	0.80(4.0%)	0.90(4.5%)	0.85(4.2%)	0.84(4.2%)	0.66(3.3%)
	4	45	1.77 (3.9%)	1.26(2.8%)	1.22(2.7%)	0.94(2.1%)	0.74(1.6%)	0.56(1.2%)
	4	90	1.78 (2.0%)	1.93(2.1%)	2.26(2.5%)	1.77(2.0%)	1.24(1.4%)	1.13(1.3%)
	8	20	0.44 (2.2%)	0.37(1.8%)	0.21(1.1%)	0.20(1.0%)	0.08(0.4%)	0.04(0.2%)
	8	45	0.52 (1.2%)	0.33(0.7%)	0.26(0.6%)	0.21(0.5%)	0.05(0.1%)	0.08(0.2%)
	8	90	0.48 (0.5%)	0.3(0.3%)	0.14(0.2%)	0.12(0.1%)	0.08(0.1%)	0.03(0.04%)
FF – new, laden with starch dust (n=4)	4	20	5.0(25.2%)	1.59(7.9%)	0.87(4.4%)	0.46(2.3%)	0.25(1.2%)	0.19(0.9%)
	4	45	3.68 (8.2%)	2.72(6.0%)	1.5(3.3%)	0.95(2.1%)	0.53(1.2%)	0.33(0.7%)
	4	90	5.74 (6.4%)	3.89(4.3%)	2.50(2.8%)	1.57(1.7%)	0.53(0.6%)	0.68(0.8%)
	8	20	1.9 (9.5%)	0.74(3.7%)	0.43(2.2%)	0.31(1.5%)	0.23(1.1%)	0.2(1.0%)
	8	45	1.69(3.8%)	1.51(3.4%)	0.83(1.8%)	0.43(1.0%)	0.28(0.6%)	0.19(0.4%)
	8	90	3.37(3.7%)	1.84(2.0%)	0.97(1.1%)	0.42(0.5%)	0.38(0.4%)	0.18(0.2%)
FF – used, laden with broiler house dust (n=4)	4	Fresh air	-0.56 (N/A)	-1.01(N/A)	-0.81(N/A)	-0.53(N/A)	-0.33(N/A)	-0.27(N/A)
	8	Fresh air	-0.5 (N/A)	-0.5(N/A)	-0.32(N/A)	-0.09(N/A)	-0.11(N/A)	-0.01(N/A)
	4	20	2.1(10.3%)	1.98(9.9%)	1.28(6.4%)	0.75(3.8%)	0.55(2.8%)	0.46(2.3%)
	4	45	6.76 (15%)	3.46(7.7%)	2.17(4.8%)	1.35(3.0%)	0.79(1.8%)	0.62(1.4%)
	4	90	15.5(17.2%)	5.61(6.2%)	2.88(3.2%)	1.35(1.4%)	0.46(0.5%)	0.10(0.1%)
	8	20	0.34 (1.7%)	0.23(1.2%)	0.25(1.2%)	0.06(0.3%)	0.16(0.8%)	0.02(0.1%)
	8	45	3.35 (7.4%)	1.95(4.3%)	1.36(3.0%)	0.81(1.8%)	0.54(1.2%)	0.49(1.1%)
	8	90	7.64(8.5%)	2.93(3.3%)	1.47(1.6%)	0.82(0.9%)	0.58(0.6%)	0.47(0.53%)
PF – new, dust free (n=3)	8	20	0.95 (4.8%)	0.48(2.4%)	0.26(1.3%)	0.11(0.6%)	0.04(0.2%)	0.03(0.1%)
	8	45	1.74 (3.9%)	0.80(1.8%)	0.51(1.1%)	0.39(0.9%)	0.26(0.6%)	0.28(0.6%)
	8	90	1.48 (1.6%)	1.49(1.7%)	1.19(1.3%)	0.84(0.9%)	0.41(0.5%)	0.43(0.5%)
	16	20	0.74 (3.7%)	0.5(2.5%)	0.21(1.0%)	0.25(1.3%)	-0.04(-0.2%)	-0.01(-0.1%)
	16	45	1.4 (3.1%)	0.30(0.7%)	0.09(0.2%)	-0.05(-0.1%)	0.07(0.2%)	0.07(0.2%)
	16	90	0.73 (0.8%)	0.63(0.7%)	0.36(0.4%)	0.28(0.3%)	0.39(0.4%)	0.06(0.06%)
TF – new, dust free, 20µm pore size (n=3)	8	20	-0.05 (-0.2%)	-0.01(-0.1%)	0.06(0.3%)	-0.06(-0.3%)	-0.08(-0.4%)	0.01(0.03%)
	8	45	0.09 (0.2%)	0.05(0.1%)	0.11(0.2%)	0.10(0.2%)	0.12(0.3%)	0.07(0.2%)
	8	90	0.26 (0.3%)	-0.12(-0.1%)	-0.19(-0.2%)	0.08(0.1%)	0.0(0.0%)	-0.01(-0.01%)
	16	20	0.27(1.3%)	-0.01(-0.1%)	0.12(0.6%)	0.06(0.3%)	-0.04(-0.2%)	0.11(0.6%)
	16	45	0.14(0.3%)	-0.20(-0.5%)	-0.09(-0.2%)	-0.10(-0.2%)	-0.04(-0.1%)	-0.09(-0.2%)
	16	90	-0.19(-0.2%)	0.04(0.05%)	0.14(0.2%)	0.08(0.1%)	0.27(0.3%)	0.09(0.1%)
TF – new, dust free, 5µm pore size (n=3)	8	20	-0.02(-0.1%)	0.09(0.4%)	0.23(1.1%)	0.19(1.0%)	0.25(1.3%)	0.04(0.2%)
	8	45	-0.15(-0.3%)	0.16(0.3%)	0.24(0.5%)	0.18(0.4%)	0.14(0.3%)	0.17(0.4%)
	8	90	0.08(0.1%)	0.07(0.1%)	-0.04(-0.05%)	0.04(0.05%)	0.01(0.01%)	-0.04(-0.05%)
	16	20	0.29(1.5%)	0.18(0.1%)	0.12(0.6%)	0.06(0.3%)	-0.04(-0.2%)	0.11(0.6%)
	16	45	0.14(0.3%)	-0.20(-0.5%)	-0.09(-0.2%)	-0.10(-0.2%)	-0.04(-0.1%)	-0.09(-0.2%)
	16	90	-0.19(-0.2%)	0.04(0.05%)	0.14(0.2%)	0.08(0.1%)	0.27(0.3%)	0.09(0.1%)
TF – used, laden with broiler house dust (n=3)	8	Fresh air	0 (N/A)	-0.01(N/A)	0(N/A)	0(N/A)	0(N/A)	0(N/A)
	8	20	0.58(2.9%)	0.27(1.4%)	0.28(0.05%)	0.29(1.5%)	0.07(0.3%)	0.05(0.3%)
	8	45	0.75(1.6%)	0.19(0.4%)	0.15(0.3%)	0.08(0.2%)	0.11(0.2%)	0.25(0.6%)
	16	20	0.33(1.6%)	0.01(0.04%)	-0.04(-0.2%)	0.01(0.06%)	0.01(0.03%)	0.14(0.7%)
	16	45	0.21(0.5%)	-0.16(-0.4%)	-0.05(-0.1%)	-0.12(-0.3%)	-0.14(-0.3%)	-0.01(-0.02%)

## CONCLUSIONS

Ammonia adsorption characteristics for some common in-line air sampling filters at different operating conditions were investigated. The filter types tested included a fuel filter, a paper filter and two kinds of Teflon filters (5 or 20  $\mu\text{m}$  pore size), being new or laden with either starch dust or broiler housing dust. The filters were subjected to combinations of three nominal inlet  $\text{NH}_3$  concentrations (20, 45, 90 ppm) and two nominal flow rates (4 vs. 8 l/min or 8 vs. 16 l/min). The following conclusions were drawn:

- Ammonia adsorption by the filter was positively related to inlet concentration, but negatively related to exposure/run time and flow rate.
- When passing fresh air through the fuel filter laden with broiler house dust, ammonia release occurred initially but diminished to nearly zero after 15 min for the flow rate of 8 l/min.
- Ammonia adsorption to the Teflon filters was negligible regardless of the inlet concentration and flow rate. Following a 30-min exposure, relative adsorption of ammonia was below 1% in most cases for the fuel and paper filters. Hence the fuel and paper filters tested in the study offer viable, more economical options for use in air emission studies.

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## REFERENCES

- Burns, R.T., H. Xin, H. Li, S.J. Hoff, L. Moody, R.S. Gates, D.G. Overhults, J.W. Earnest. 2006. Monitoring system design for the Southeastern broiler gaseous and particulate matter air emissions project. In Proceedings of the Symposium on Air Quality Measurement Methods and Technology, May 9-11, 2006, Sheraton Imperial Hotel and Convention Center, Durham. NC. Paper # 042806, Air and Waste Management Association.
- Capareda, S.C., C.N. Boriack, S. Mukhtar, et al. 2004. recovery of gaseous emission from ground level area sources of ammonia and hydrogen sulfide using dynamic isolation flux chambers. Technical paper No. 044013. American Society of Agricultural Engineers, St. Joseph, MI: ASAE
- Demmers, T.G .M., L.R. Burgess, V.R. Philips, et al. 2000. Assessment of techniques for measuring the ventilation rate, using an experimental building section. *J. Agric.Eng. Res.* 76(1): 71–81.
- Demmers, T.G. M., V.R. Philips, L.S. Short, et al. 2001. Validation of ventilation rate measurement methods and ammonia emission from naturally ventilated dairy and beef buildings in the United Kingdom. *J. Agric. Eng. Res.* 79(1): 107–116.
- Gates, R.S., K.D. Casey, H. Xin, E.F. Wheeler, and J.D. Simmons. 2004. Fan Assessment Numeration System (FANS) Design and Calibration Specifications. *Transactions of the ASAE* 47(5): 1709-1715.
- Gates, R. S., H. Xin, K. D. Casey, Y. Liang, and E.F. Wheeler. 2005. A method for measuring ammonia emissions from poultry houses. *Applied Poultry Res.* 14: 622-634.
- Heber A. J., J.-Q. Ni, B. L. Haymore, et al. 2001. Air quality and emission measurement methodology at swine finishing buildings. *Transactions of the ASAE* 44(6): 1765-1778.

- Lee J. and Y. Zhang. 2006. Determination of ammonia and odor emissions from animal building dusts. Technical paper No. 064210. American Society of Agricultural and Biological Engineers, St. Joseph, MI: ASABE
- Li, H., H. Xin, Y. Liang, R. S. Gates, E. F. Wheeler, and A.J. Heber. 2005. Comparison of direct vs. indirect ventilation rate determinations in layer barns using manure belts. *Transactions of the ASAE* 48(1): 367-372.
- Li, H., Xin., H., R. Burns 2006. Reduction of Ammonia Emission from Stored Poultry Manure Using Additives: Zeolite, Al+clear, Ferix-3 and PLT. Paper #064188. ASABE Annual International Meeting. ASABE. St. Joseph, MI
- Liang, Y., H. Xin, H. Li, R.S. Gates, E.F. Wheeler and K.D. Casey. 2006. Effect of measurement interval on estimation of ammonia emission rates for layer houses. *Transactions of the ASAE* 49(1): 183-186.
- Liang, Y., H. Xin, S. J. Hoff, and T. L. Richard. 2004. Performance of Single Point Monitor in measuring ammonia and hydrogen sulfide gases. *Applied Engineering in Agriculture* 20(6): 863-872.
- Muhlbauer, R.V., T. Shepherd, H. Li, R.T. Burns, H. Xin. 2006. Development and testing of a fan monitoring system using induction operated current switches. Paper # 064159. ASABE Annual International Meeting. ASABE. St. Joseph, MI
- Mukhtar S., A.J. Rose., S.C. Capareda, et al. 2003. Assessment of ammonia adsorption onto Teflon and LDPE tubing used in pollutant steam conveyance. *Agricultural Engineering International: the CIGR Journal of scientific research and development*. Manuscript BC 03 012 Vol. V. Paper 29, 1-13.
- Phillips V.R., M.R. Holden, R.W. Sneath, et al. 1998. The development of robust methods for measuring concentration and emission rates of gaseous and particulate air pollutants in livestock building. *J. Agric. Engng. Res.* 70: 11-24
- Takai, H., K. Nekomoto, P.J. Dahl, E. Okamoto, S. Morita, and S. Hoshiba. 2002. Ammonia Contents and Desorption from Dusts Collected in Livestock Buildings. *Agric. Eng. Int.: the CIGR*
- Wathes, C.M., V.R. Phillips, M.R. Holden, et al. 1998. Emissions of aerial pollutants in livestock buildings in northern Europe: Overview of a multinational project. *J. Agric. Eng. Res.* 70(1): 3-9.
- Wheeler, E.F., K.D. Casey, R.S. Gates, H. Xin, J.L. Zajackowski, P.A. Topper, Y. Liang, A. J. Pescatore. 2006. Ammonia emissions from twelve U.S.A. broiler chicken houses. *Transactions of the ASAE* 49(5): 1495-1512.
- Xin, H. 2006. United Egg Producers initiative on air emission mitigation. In: Proc of the National Poultry Waste Management Symposium, October 23-25, 2006, Springdale, AR.
- Xin., H., H. Li, R. Burns, R. Gates, D. Overhults, J. Earnest, L. Moody, S. Hoff. 2006. Use of CO<sub>2</sub> concentrations or CO<sub>2</sub> balance to estimate ventilation rate of modern commercial broiler houses. Paper #064156. ASABE Annual International Meeting. ASABE. St. Joseph, MI
- Xin, H., T. Wang, R.S. Gates, et al. 2002. A portable system for continuous ammonia measurement in the field. Technical paper No. 024168. American Society of Agricultural Engineers, St. Joseph, MI: ASABE
- Xin H., Y. Liang, A. Tanaka, et al. 2003. Ammonia emissions from U.S. poultry house: part I – measurement system and techniques. Proc of the third international conference on air pollution

from agricultural operations held on October 11-14, 2003 in Raleigh, NC, organized by ASAE, St. Joseph, MI

Zhang G., J.S. Strom., B. Li, et al. 2005. Emission of ammonia and other contaminant gases from naturally ventilated dairy cattle buildings. *Biosystems Engineering* 92(3):355–364